# APPENDIX A

# EXISTING ENERGY PROFILES

## INTRODUCTION

In order to identify the potential benefits resulting from the addition of on-site photovoltaic installations (PV) at NJDOT, it is important to evaluate the current energy demand, consumption, and cost characteristics at candidate facilities. This task was accomplished through the analysis of the 2009 monthly electricity and gas bills for three selected sites: NJDOT Headquarters campus (Ewing), the Newark Maintenance Facility (Newark), and the Mt. Arlington Regional Headquarters (Mt. Arlington).

## DATA AND METHODOLOGY

The three selected facilities vary widely in terms of electricity consumption, number and complexity of connections/meters, rates/tariffs, and electricity providers. In order of increasing complexity, the utility configurations are:

- **Mt. Arlington:** One meter each for electricity and gas. Electricity is supplied by Jersey Central Power and Light, and gas is supplied by New Jersey Natural Gas.

- **Newark:** One main electric connection and a second, smaller, electric account as well as multiple natural gas hookups. All accounts are serviced by PSE&G, although Hess Corporation supplies gas through a commodity contract.

- **Ewing:** Three main electrical connections (in order of consumption: E&O Building, F&A/Fernwood complex, Thiokol 2-5 and 9) and nearly a dozen smaller, often minor, electric accounts. Ewing has multiple natural gas accounts; the most significant gas connection is for the Central Steam Plant. PSE&G delivers both electricity and gas, but Pepco Energy Services is the commodity supplier for F&A and E&O through a contract procured by the New Jersey Department of the Treasury. Hess Corporation supplies natural gas for smaller accounts, although PSE&G supplies the Central Steam Plant.[1]

2009 monthly utility data for these accounts was obtained from multiple sources, entered into Excel, and analyzed. The quality and comprehensiveness of utility data varied by facility:

- **Mt. Arlington:** Full utility usage data for the 2009 year was available.

- **Ewing and Newark:** PSE&G, which supplies both electricity and gas, provided data only from March 2009 through November 2009, leaving the three winter months of December, January, and February incomplete. This data was supplemented with electricity bills for December 2009 and January 2010 for the largest accounts (Thiokol 2-5 and 9, E&O, and F&A plus Fernwood for Ewing and 524-560 Route 1 for Newark). To address remaining data gaps (February 2009

[1] Customers in New Jersey may choose power suppliers other than their home utility, whether for favorable rates or environmental attributes. The home utility remains responsible for energy delivery.

for the aforementioned accounts and December through February for the minor Ewing and all Newark accounts), we estimated energy use and cost based on available data from adjacent months, accounting for common seasonal energy fluctuations (slightly reduced electric and slightly increased gas usage during midwinter months). The CS Team considers estimation of winter usage to be acceptable practice, as these months do not typically drive peak usage or costs, and therefore are not expected to influence the potential PV capacity for the site.

- **Newark:** The data provided by PSE&G omitted all peak demand information. Because only annual peak demand is critical for sizing renewable energy installations (due to New Jersey state net metering laws), the CS Team obtained monthly bills only for the traditional peak months of July and August as well as March, during which the greatest kWh consumption occurred.

The monthly data for each selected site were then analyzed, with particular attention placed on factors that affect the sizing of renewable energy installations: annual and seasonal peak demand, monthly consumption, and monthly demand and consumption charges.

## FINDINGS

Preliminary review of the data led to the identification of five electricity accounts with the greatest potential to accommodate PV:

**Mt. Arlington:** The sole electricity account at this facility features a substantial 2009 peak demand figure of 163 kW, although this is down from over 200 kW the previous year. Consumption was 688,960 kWh, costing $104,119. The load factor was 48 percent.[2] Monthly kWh consumption does not follow the typical bell shaped profile showing lower electricity consumption during winter months and progressively higher summer consumption due to increased cooling loads and operating durations for air conditioning, usually peaking in August or July. Instead, Mt. Arlington's greatest consumption is in February, followed by January, July/August, and September. However, 2008 data yields a more conventional profile. Overlaying the demand and consumption curves for 2008 and 2009 shows that, while winter, spring, and fall months track very similarly (with modest aberrations expected), summer figures from 2008 are notably higher that their 2009 counterparts. Assuming that these billings are accurate, this may indicate a drastic change in summertime use or, more likely, the replacement, modification, and/or rebalancing of major building systems, such as chillers.

**Newark:** Of Newark's two electricity accounts, one handles almost 99.8 percent of the facility's total consumption of 568,899 kWh (the other appears to be connected to a light in the storage yard). Peak demand was 132 kW, and total costs were estimated to be $88,545. The load factor was 49 percent. The consumption profile for this facility was atypical, showing heavy usage in late winter and early spring and modest summer peaks. This pattern may result from the maintenance facility's unique usage characteristics.

**Ewing – Thiokol 2-5 and 9:** The Thiokol account follows the classic bell shaped profile, with pronounced increases in consumption in July and August, tapering off quickly thereafter. Total consumption was 2,206,704 kWh (almost 16 percent of Ewing's total), with a peak of 611 kW, yielding a load factor of 41 percent. Electricity rates rise significantly from June through September as summer demand charges take effect. The total annual energy cost was estimated to be $349,951.

**Ewing – E&O:** The E&O account, which covers most of the MOB and E&O buildings, is Ewing's single largest account in terms of consumption: 6,368.500 kWh, or over 45 percent of total consumption. Peak demand was 1.17 MW (load factor was 62 percent). The greatest monthly consumption occurred in March, for unknown

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[2] Load factor is defined by the U.S. Energy Information Administration as "the ratio of the average load to peak load during a specified time interval." In this case, the time interval is one year, or 8,760 hours. A load factor of 1 (100 percent) would indicate that the facility draws peak kW at all times. Lower load factors may indicate greater feasibility for PV, which lowers demand during typical peak periods and months, thereby reducing associated demand charges. Lower load factors may also improve the prospect of generating excess kWh over an annualized period, which, under NJ net metering laws, may be sold back to the utility at wholesale rates.

reasons, although the peak occurred in August and summer months show, on average, modestly higher consumption than fall or winter months. This account is supplied by Pepco, which leads to a fairly uniform month-to-month rate per kWh, except from June through May, when rates increase due to the application of summer demand charges. Total yearly charges are estimated to be $883,159.

**Ewing – F&A:** The F&A account covers a multitude of facilities with a variety of physical configurations and usage characteristics, including the F&A building, most of the Fernwood facilities, parking lot B, and the vacant Foran buildings. F&A accounts for over 33 percent of Ewing's consumption, with 4,667,898 kWh, and possesses the highest peak demand of any account examined, at 1.21 MW (load factor of 45 percent). F&A's consumption profile is conventional, with easily distinguishable peaks for July and August and more moderate peaks for June and September. Like E&O, because this facility is supplied by Pepco, the rate per kWh is stable from month to month, save for June to September. Total annual charges are estimated to be $647,516.

**Ewing (total):** Ewing is comprised of several accounts, the total consumption of which was 13,943,684 kWh, costing an estimated $2 million. The sum of all peaks is 3.1 MW, although this figure is irrelevant as the sizing of renewable energy installations is dependent on the peak demand for each individual meter (the customer-generator may not feed back more power, in kW, than it receives from the utility). Moreover, not all of these peaks coincide, although most occur during the summer months.

**Table 1. Ewing Electrical Summary (2009)**

| Facility | | Peak kW | 2009 kWh | Yearly Cost | Avg. Cost/kWh |
|---|---|---|---|---|---|
| Ewing | Thiokol 2,3,4,5,9 | 611 | 2,206,704 | $349,951 | $0.16 |
| Ewing | E&O | 1,170 | 6,368,500 | $883,159 | $0.14 |
| Ewing | F&A + Fernwood #22 | 1,210 | 4,667,898 | $647,516 | $0.14 |
| Ewing | 940 Lower Ferry Rd | 16 | 25,213 | $4,860 | $0.19 |
| Ewing | W Farrell Ave | N/A | 11,887 | $2,772 | $0.23 |
| Ewing | 1035 Parkway Ave | 5 | 93,025 | $17,984 | $0.19 |
| Ewing | Lower Ferry Rd Rear | 30 | 51,020 | $9,192 | $0.18 |
| Ewing | 999 Parkway Ave | 16 | 26,848 | $5,465 | $0.20 |
| Ewing | 946 Lower Ferry RD | N/A | 13,971 | $3,071 | $0.22 |
| Ewing | 930 Lower Ferry Rd | N/A | 15,223 | $3,126 | $0.21 |
| Ewing | 930 Lower Ferry Rd | 102 | 376,515 | $9,819 | $0.16 |
| Ewing | 942 Lower Ferry RD | 4 | 4,246 | $718 | $0.17 |
| Ewing | Lower Ferry RD | 40 | 82,635 | $5,187 | $0.18 |
| **Ewing** | **SUM of Ewing** | **3,100** | **13,943,684** | **$2,002,821** | **$0.14** |

# APPENDIX B

## SUMMARY SCAN OF SCALABLE RENEWABLE ENERGY TECHNOLOGIES

## INTRODUCTION

This memo employs a simple, straightforward process for selecting and reviewing technologies:

1. A comprehensive list of technologies was culled from the U.S. Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL).

2. The following parameters were designed to screen out unsuitable technologies, allowing for closer focus on options that offer greater promise for application at NJDOT:

   (a) The technology must enable the generation of energy without the importation of feedstock. For this reason, anaerobic digester gas technologies, biomass, and hydrogen fuel cells were not reviewed.

   (b) The technology must be a net energy generator. Thermal storage – for example, the generation of ice overnight during off-peak hours for cooling during daytime peak hours – is therefore not eligible.

   (c) The technology must be scalable/easily accommodated on-site. Large-scale wind turbines, concentrated solar, and geothermal power, for example, all require significant amounts of dedicated space and could not be practically accommodated at the NJDOT sites.

   (d) The technology must not require energy resources unavailable at the selected sites (NJDOT Headquarters Complex, Mt. Arlington Regional Headquarters, and Newark Maintenance Yard). For example, small-scale hydropower must have direct access to a suitable water resource.

   (e) The technology must be sufficiently mature. For example, tidal power (even if an adequate tidal resource were available) is not yet employed at any major commercial installation in the United States (Verdant Power's New York City tidal project, for instance, is still in the pilot phase as of this writing).

   The notable exception is *Energy Efficiency and Energy Conservation Measures*. While these technologies and strategies cannot be said to generate energy, they are – when applied appropriately – net energy savers. It is important to recognize that pairing energy efficiency with renewable energy technologies offers the potential to greatly improve project outcomes, both environmentally and financially. This screening process yielded five technologies for further review.

3. All five technologies were reviewed using a basic framework, of which the substantive sections were "Technology" and "Applications and Characteristics." The "Technology" section is where a basic description of how the technology works is constructed, including information on the renewable resource harnessed (E.g., wind, solar, etc.) and the general process through which that resource is

transformed into usable energy. "Applications and Characteristics" is where potential strategies for implementation are reviewed.

DOE and NREL served as the primary informational resources, although the Lawrence Berkeley National Laboratory, U.S. Environmental Protection Agency (EPA), U.S. Energy Information Administration (EIA), the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the Federal Aviation Administration (FAA), and various state government-affiliated sources were utilized as circumstances dictated (the California Energy Commission, for example).

Reputable nongovernmental sources, such as the U.S. Green Building Council (USGBC), the Electric Power Research Institute (EPRI), and various university-sponsored research institutes (Texas A&M, the University of Oklahoma, and MIT among them) also were important sources. More rarely, information from renewable energy installers, manufacturers, and industry groups (such as the American Wind Energy Association) was used to provide minor clarifications or for equipment pricing; due to the bias inherent to these types of sources, no information critical to determining project feasibility is cited from these sources.

4. The five technologies were then examined in relation to one another to determine which was most suitable for a focused feasibility review. A basic scoring matrix was developed for this task, although, given the necessity to narrow down before performing more thorough investigations, it was not intended to function as a precise means of comparison. Rather, the categories of evaluation the matrix establishes, the inputs it uses, and the scores it outputs, are necessarily broad. Therefore, scores for each category also were broad – "*low*" ( ), "*medium*" ( ), and "*high*" ( ). The categories were:

   a. **Site:** The suitability of the technology given the sites selected by NJDOT;

   b. **Energy:** The ability of the technology to provide reasonable energy output (in context) and the environmental impact of the technology;

   c. **Cost:** The relative cost of the energy produced, given first costs, operating costs, incentives, and conventional energy costs;

   d. **Local:** The presence of installers/developers in New Jersey and in the region, and support for the technology at the state and national levels.

| EXAMPLE | |
|---|---|
| Category | Rating |
| Site | |
| Energy | |
| Cost | |
| Local | |

Based on the matrix-based review, this memo recommends focusing on solar photovoltaics (PV) for a context-specific feasibility study.

While solar PV is the recommended technology going forward, the other technologies reviewed can play crucial roles in NJDOT's future renewable energy initiatives. No one solution is ideal for all circumstances. Wind and solar, for example, are usually good complements; whereas solar resources are strongest during the day, wind resources generally increase at night. Solar thermal technologies and ground source heat pumps are highly effective technologies that often require electricity for mechanical processes – electricity that could be supplied by photovoltaics. And energy efficiency measures can provide cost-effective solutions to reducing loads, thereby reducing the size or increasing the efficacy of PV installations.

## SOLAR PHOTOVOLTAICS

### Overview

| PHOTOVOLTAICS | |
|---|---|
| Category | Rating |
| Site | |
| Energy | |
| Cost | |
| Local | |

Solar photovoltaic (PV) systems harvest energy directly from sunlight, in the form of direct current (DC) electricity. PV provides unique flexibility, from rigid, mounted panels to building-integrated thin film membranes, and is highly scalable. Applications range from handheld consumer electronics to residential, one-kilowatt systems to major, multi-megawatt commercial applications. With the addition of equipment to invert electricity from DC to AC, photovoltaics can produce usable energy for existing facilities without necessitating major system overhauls or replacements.

New Jersey has been among the County's greatest proponents of PV and offers a wide range of incentives. New Jersey ranks second among all States – behind only California – in installed PV capacity,[3] with over 100MW as of fall 2009, and has aggressive plans to continue expanding its leadership in solar PV in the future.

[3] Capacity (also referred to as "Nameplate Capacity"), is the theoretical maximum output, at any given moment, by the energy-generating equipment. Output, however, is a measure of the actual energy generated by that equipment over time. The output of renewables is almost always much smaller than the capacity, due to equipment inefficiencies and resource limitations.

## Technical Description

The building block of the technology is the photovoltaic cell, comprised of two layers of semiconductor (most often silicon). The photons in sunlight can energize the electrons in the semiconductor, which are then released. A wire, connecting the layers as a circuit, provides an outlet for the electrons, which can be diverted to power an electrical load or charge a battery.

Like most renewables, the power production (kWh) of PV is dependent on a number of factors both internal and external to the system. Of internal factors, conversion efficiency is critical; of the photons that strike the PV cell, only a certain portion are absorbed and produce electricity. NREL data shows current commercial PV conversion efficiencies of approximately 7 percent to 17 percent, although efficiencies of nearly 40 percent have been achieved with experimental materials and cell structures.

The original, and still most prevalent, PV systems were comprised of rigid crystalline silicon panels (the semiconductor), often mounted on a racking apparatus, which may be flat, fixed-angle, or variable angle. Currently, a variety of additional semiconductors are in use which allow for a wider variety of applications, most notably flexible, thin film PV, which can be integrated into roofing membranes, building siding, or even placed over windows.

The primary external factor for power production is insolation (*in*cidence of *sol*ar radi*ation*), a measure of the solar radiation energy reaching a given space in a given time. Areas with fewer average hours of sunlight (Direct Normal Irradiance or DNI) and cloudy, hazy, or polluted atmospheric conditions receive less insolation; New Jersey, with a modest annualized DNI of 4.2 hours per day, has a lower insolation rate than most Southwestern states, for example.[4]

## Applications and Characteristics

Solar PV's inherent benefits include scalability and flexibility. In concept, a photovoltaic system can range from a few cells, providing less than a watt for a solar calculator, to a large, multi-megawatt array with hundreds of panels. Systems may feature panels which are mounted (fixed and one or two axis) or set flat on rooftops, on the ground, poles, canopies, or a multitude of other structures or surfaces. With the addition of thin film panels, PV can be integrated into roofing membranes, siding, windows, and a host of other applications. While – from the standpoints of cost, power production, and regulatory issues – it may not be desirable to place PV on every roof, every lawn, and over every window, the wide variety of available PV systems make it possible.

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[4] This data is available from NREL for the entire United States or from NASA for specific sites (latitude/longitude): http://aom.giss.nasa.gov/srlocat.html.

PV can generate significantly more energy during summer months than in winter. Fortunately, electricity consumption is typically highest during hot summer days (due to air conditioning, primarily) and unit charges are significantly more expensive during peak periods. A properly sized PV system allows a utility customer to engage in "peak shaving" – essentially removing the peak of the utility-purchased power curve by substituting electricity generated on-site.

A few basic limitations should be considered when siting a PV array:

- PV cells should be exposed to direct sunlight (DNI); a panel placed in a shaded area or covered by vegetation will not perform optimally;
- Panels require proper orientation and angling;
- Proper panel ventilation also is important; solar PV is powered by photons – not by heat. Like most semiconductors, cell performance diminishes with excessive heat (called "heat fade"); and
- PV systems can be fragile – to ensure long-term performance, both panels and films should be placed in locations that are generally inaccessible to the public.

**Matrix Review**

- **Site ( ):** PV is highly scalable, and can be installed in a variety of configurations, with few restrictions.
- **Energy ( ):** While New Jersey has only modest solar resources, a sizeable array could contribute meaningfully to building loads and could be exported to the grid. Additionally, maximum PV production often occurs during peak periods, helping to "shave" loads when power is most expensive. Finally, electricity, the energy product from photovoltaics, is much easier to integrate into existing buildings than thermal energy.
- **Cost ( ):** PV payback periods are often longer than thermal energy technologies, but electricity can be exported to the grid and is eligible for Renewable Energy Certificates (RECs). New Jersey provides a particularly supportive financial environment for PV.
- **Local ( ):** New Jersey has the second most installed nameplate PV capacity in the country, behind only California (with far superior solar resources and a much higher load). New Jersey has a plethora of manufacturers, installers, and developers that specialize in large-scale solar. This situation is the direct product of a policy framework that champions solar in New Jersey.

## SOLAR THERMAL

### Overview

| SOLAR THERMAL | |
|---|---|
| Category | Rating |
| Site | ▯ ▯ |
| Energy | ▯ ▯ |
| Cost | ▯ ▯ ▯ |
| Local | ▯ ▯ |

In addition to generating electricity, sunlight can provide thermal energy for building heating, ventilation, hot water, and, more rarely, cooling. Solar energy can be collected actively (which requires additional process energy) or passively, as with solar-oriented buildings or gravity-based water heating systems. Generally, first costs are high relative to conventional systems, while operating costs are low. Thermal energy is often more challenging to integrate into existing building systems than electrical energy.

### Technology

#### Air Heating

Large buildings, in particular, often require ventilation in order to achieve acceptable interior air quality for occupants. In colder weather, outside air requires preheating before it can be distributed, an energy intensive process. In many contexts, the sun can be harnessed for this job through the installation of a transpired collector. The collector is typically composed of a thin, hollow, and perforated black metal panel, mounted on a south-facing wall. Ambient air flows through the perforations and is heated by sunlight while inside the panel (a space called the plenum). Subsequently, the warmed air is drawn into the building by a fan, after which it is distributed through ductwork.

#### Solar Hot Water

Exterior sunlight collectors can also be employed to produce water for use in a domestic hot water system or, in some cases, for space heating. The collector is most often a flat plate model, but linear concentrators and evacuated tube models can be used as well. A flat plate collector is composed of an outer layer of glass, a series of fluid-filled tubes (water or an antifreeze solution), and a black backing. This unit is typically mounted on a pitched, southern-facing roof. As sunlight heats the fluid, it is pulled into a heavily insulated storage tank or to a boiler/water heater, which can add supplemental heat to the water if needed (typical of a space heating system). If non-water fluids are used in the solar collector, they may be fed through a coil or heat exchanger which transfers heat to the relevant water system (domestic or heating).

## Solar Cooling

Solar cooling can be accomplished through solar absorption or solar desiccant systems. Solar absorption involves using solar energy to evaporate a refrigerant, while solar desiccant systems remove moisture from the air, thereby reducing the latent cooling load required. According to NREL, solar cooling is very expensive and not widespread in the United States. Therefore, it will not be considered further.

### Applications and Characteristics

Like solar photovoltaics (PV), the suitability of solar thermal applications depends on the quality of solar resources (hours of Direct Normal Irradiance per year, for example) and the efficiency of the equipment. Unlike PV, however, the peak production periods for solar thermal do not typically coincide with peak demand periods. The need for warmed air, for instance, is usually greatest at the time of year when hours of sunlight are fewest. Therefore, in almost all cases solar thermal applications must be supplemented with a conventional backup. Nonetheless, solar thermal technologies are often relatively cost-effective and efficient, depending on the specific use and the climate.

A significant potential drawback to solar thermal energy arises when considering the deployment of these systems in existing buildings. The integration of solar thermal may require extensive, costly reconfiguration or outright replacement of current heating and/or cooling systems.

## Air Heating

Space heating technologies are most relevant to larger commercial or industrial buildings which require ventilation in moderate to cold climates. According to the U.S. Department of Energy, each square foot of collector will raise the temperature of 4 cubic feet of air per minute by 40 degrees Fahrenheit. In northern New York, for example, the Science Applications International Corporation (SAIC) found that system payback could occur in as little as 2 years if natural gas were $24/Mbtu, or in as many as 17 years if gas cost only $3/Mbtu. As with all renewable technologies, the prospect of solar thermal grows more attractive as conventional fuels increase in price.

## Solar Hot Water

Solar hot water collectors can be employed in both residential and commercial/industrial contexts that require large and consistent quantities of domestic or heating hot water. Solar hot water becomes a more compelling option when solar resources are sufficient, adequate southern-facing roof space is available, and conventional hot water heating is expensive (usually related to higher natural gas prices). These systems must be backed up by conventional hot water sources.

### Matrix Review

- **Site ( ):** Solar thermal technologies are generally scalable, with few restrictions on installation (although, unlike solar PV, solar thermal installations are usually

building mounted and distribution from the solar installation to the building incurs greater energy losses than does PV).

- **Energy (➲):** New Jersey's solar resources are modest and solar thermal technologies would require conventional backups. Nonetheless, solar thermal installations have the potential to contribute meaningfully to the reduction of heating loads.

- **Cost (➲⇧):** Solar thermal paybacks can be relatively short if conventional fuels are expensive. However, compared to PV, the integration of thermal energy into existing buildings typically also presents greater challenges and potential costs (i.e., electricity is an immediately usable output, whereas thermal energy may require extensive system modifications).

- **Local (➲):** Qualified installers are widely available in the Tri-State area. While a pilot homeowner rebate program is available, few New Jersey state incentives specific to solar thermal exist.

## SMALL WIND

### Overview

| SMALL WIND[5] | |
|---|---|
| Category | Rating |
| Site | ⇩➲ |
| Energy | ➲⇩ |
| Cost | ➲⇩ |
| Local | ➲ |

Wind energy is the fastest growing and most prevalent form of renewable energy in the United States. Installed nameplate capacity grew 10 fold from 2000 to 2008 to over 25,000 MW, generating over 50 million kWh – surpassing Germany for the world lead. Recently, national policy has been very favorable toward wind energy, resulting in a host of incentives (especially the Production Tax Credit or PTC) that, at the conclusion of 2008, had lowered the price of wind generated electricity to $.04 per kWh – a price competitive with fossil fuel generated electricity. And wind energy is exceptionally environmentally friendly, even among renewables. From a life-cycle perspective, GHG emissions from large wind projects are a full order of magnitude lower than solar PV (and two orders lower than fossil sources), per kWh produced.

However, most wind installations are rural, large-scale, and sited in order to utilize abundant natural wind resources. Typically, the power production and energy cost

[5] Of the cells that contain two ratings, the rating on the right refers to small turbines on towers. The rating on the left pertains to micro, building-integrated wind installations.

benefits associated with large wind projects diminish significantly for smaller urban or suburban installations.

## Technology

Wind energy is created primarily by uneven solar heating, resulting in pressure differentials that accelerate air in an attempt to equalize. Wind speed and uniformity are particularly localized phenomena, affected greatly by ground cover, structures, and topography (all of which contribute to an inherent disadvantage for many urbanized areas), but are generally best where friction is lowest – at altitudes well above the ground. Wind resources generally intensify during the night (particularly above the ground plane) and during the winter months. As such, wind and solar offer roughly opposite power curves, making the two ideal complements where both resources are adequate.

At a certain speed, wind creates sufficient air resistance to turn turbine blades, which can be oriented horizontally (HAWT) or vertically (VAWT). Blades are linked, via a shaft, to a gear box, which in turn feeds into a generator (housed at the back of the nose cone in typical "windmill" configurations). For modern turbines, a yaw drive helps orient the blades to the strongest winds to achieve greater production, although yawing is less effective as wind turbulence increases.

As with most renewables, wind energy output is determined by factors relating to the size and efficiency of the "collecting" equipment, such as the turbine (specifically the blade length), and the availability and quality of the resource being collected. The size, configuration, and mechanical efficiency of the turbine all factor into the turbine's nameplate capacity – the amount of energy it could generate under ideal conditions. In the field, the ability of the turbine to generate energy is limited by wind speeds and turbulence, both which are highly variable. The actual amount of energy created by the turbine divided by the amount of energy that, theoretically, could have been produced at maximum capacity, is known as the capacity factor.[6] Capacity factors for large wind applications currently range from 20 to 40 percent, indicating a variability that creates challenges to the integration of wind energy in smaller markets. Small wind, and particularly micro, building-integrated wind, often suffer from considerably lower capacity factors.[7]

## Applications and Characteristics

The Plains states, with vast expanses of flat ground, offer some of the Country's best winds (fast without significant turbulence), as do offshore locations along both the East

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[6] For example, a 1kW nameplate system could produce 8,765 kWh in a year at maximum capacity (8,765 hours in a year). If the system actually produces 2,000 kWh, then the capacity factor is 22.8 (2,000/8,765 = 22.8 percent).

[7] See, for example, "Assessing the Value of Small Wind Turbines": http://www.nytimes.com/2008/09/04/business/04wind.html.

and West coasts. New Jersey, however, possesses relatively modest wind resources (29th in the Nation), especially in non-coastal regions (Trenton, for instance, does not even register on NREL's wind resource maps). This fact is reflected by a marked paucity of wind projects; according to U.S. DOE, New Jersey had only eight (8) installed MWs of capacity in 2008. New York State, by comparison, had over 830 MW (due to upstate wind farms), and Pennsylvania had over 361MW installed. Texas, the national leader, had 7,118 MWs installed.

Although currently turbines run the gamut from 6MW (which requires 450-foot towers) to 600 watts, a vast majority of wind energy capacity is from very large-scale developments. Only 0.5 percent of all turbines installed in 2008 were 500kW or less, and only 10 percent were below one MW. "Large wind" projects involve the installation of dozens, potentially hundreds, of large towers with massive turbine blades; 1.5 MW turbines, with blade sweeps of over 200 feet, are most widely used, although 2.5 and 3.5 MW units (280 to 330ft sweeps) are growing in prevalence. The siting of large wind requires relatively undeveloped locales (or offshore sites), often situated a significant distance away from major load centers.

In more urbanized areas, smaller-scale (100kW or less) horizontal wind turbines, vertical axis turbines, and building-integrated microturbines surmount many siting challenges. However, smaller turbines still require significant towers; even a 100 kW unit has a 60-foot sweep, requiring, at minimum, an 80-foot tower – and faster, less turbulent winds require greater heights. In addition to visual impacts, other popularly cited concerns in densely populated areas include noise and safety, including ice throw (the catapulting of ice and snow by turbine blades), and bird and bat strikes. Although most small wind impacts can be effectively mitigated, negative public perception, restrictive zoning, and permitting hurdles remain potential impediments to project implementation. Finally, wind energy benefits greatly from economies of scale – more turbines, larger turbines, greater turbine heights, and, generally, better wind resources contribute enormously to project success. Smaller, urban and suburban projects are more likely to suffer from poor power production due to small nameplate capacity and wind resources of significantly lower quality.

### Matrix Review

- **Site (↓→):** Even small turbines typically require tower heights of 60 feet or more in order to access laminar (not turbulent) wind flows. Micro, building-integrated turbines are generally significantly easier to site.

- **Energy (→↓):** Larger turbines provide substantial quantities of energy, although, due to the variability of wind, it is not suitable for baseloads. Micro turbines often provide negligible energy.

- **Cost (→↓):** Large commercial turbines deployed by utilities and power merchants are nearly cost competitive with natural gas in some areas. Smaller turbines can provide power at reasonable rates (10 to 50 cents), but are generally not cost competitive with utility rates. Micro turbines can be very expensive on a per kWh basis (oftentimes over $1/kWh).

- **Local (→):** Non-coastal New Jersey is not endowed with notable wind resources, and urbanized areas generally provoke too much turbulence for efficient power production.

## GROUND SOURCE (GEOTHERMAL) HEAT PUMPS

### Overview

| GEOTHERMAL | |
|---|---|
| Category | Rating |
| Site[8] | →↓ |
| Energy | ↑ |
| Cost | → |
| Local | → |

By leveraging the moderate temperatures found just below the earth's surface, ground source (or geothermal) heat pumps exchange thermal energy between buildings and the ground, which serves as a heat source in the winter and a heat sink in the summer. In 2004, experts estimated that over a million ground source heating systems were in use worldwide, comprising over 12 GW of thermal energy capacity.

Geothermal heat pumps are distinct from geothermal power, which utilizes steam created deep – typically a mile or more – within the earth to generate electricity or thermal energy. Geothermal resources are generally poor in the eastern half of the United States and geothermal power plants incur significant upfront capital costs.

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[8] As explained later in the text, a horizontal system requires a substantial amount of space, but more compact vertical systems incur drilling expenses that may impact project feasibility.

## Technology

Like the more widely used air-source heat pump, a geothermal pump uses mechanical processes to facilitate the exchange of heat between a thermal source (when heating) or sink (when cooling). However, air can be problematic as a source or sink given its high degree of variability. As air temperatures progress farther toward extremes of cold or hot, the coefficient of performance (essentially efficiency) drops dramatically – the greater the differential between inside and outside (i.e., when the system is needed most), the more energy is required to operate the heat pump.

Geothermal heat pumps utilize a fluid, usually water or an antifreeze solution, as an exchange medium to transfer heat to and from the ground, a process known as geoexchange. In the common "closed loop" application, the fluid must have ample opportunity to equalize with the ground temperature in order to effectively gather or deposit thermal energy. This process commonly requires a long "loop" of tubing, oriented vertically or horizontally (as a single loop or series of loops traveling a considerably distance down and up or out and back) or "slinky" style (a series of flexible tubes coiled tightly to reduce the size of the installation space while maintaining adequate loop length). Vertical systems require a smaller footprint, can be installed in rocky ground, and require less tubing, but also necessitate expensive drilling.[9] Horizontal systems require a much larger footprint and more tubing due to seasonal temperature fluctuations not found at greater depths, but trenching is less expensive than drilling. Slinky systems provide for more linear feet of tubing within a smaller or shallower space, and can be installed vertically or horizontally. Open loop systems also are available and are often more efficient, but require an adequate supply of suitable ground water for recharge and discharge.

Like air-source pumps, thermal energy from the ground-embedded fluid loops is transferred to a heat exchanger, which is connected to an electrically driven compressor. The compressor extracts heat from the ground source during heating season and rejects heat to the ground source during cooling season. Heating and cooling can be distributed to the building either via ductwork (air) or hydronically/ radiantly (water), as with other centralized heating and cooling methods. Heating and cooling functions are toggled by a refrigerant reversing valve.

## Applications and Characteristics

In the United States, most geothermal heat pump systems serve smaller loads, often for detached residences. The California Energy Commission, for example, estimates that an average home requires a three-ton system. At the opposite, and far rarer end of the spectrum, the Galt House East Hotel and Waterfront Office Building have over 4,700 tons of installed geothermal (aquifer) heating and cooling. The City of Toronto uses

[9] The California Energy Commission cites $10,000 to $30,000 in drilling for a vertical loop residential system, which could increase many fold for a larger commercial system.

deep lake cooling (using cold Lake Ontario water as a heat sink) for a large-scale downtown district cooling system.

Although there is no substantial mechanical difference between a three-ton and 4,700-ton system and no theoretical limit to the load that could be served, the technology is likely to be impractical for larger buildings in urban settings – particularly so for pre-existing buildings. Depending on the type of loop, depth, soil conditions, and climate, ground source heat pump systems can require from 250 to 1,000 feet of tubing per ton of heating and cooling. Using a conservative 500 feet per ton, a single family house might easily accommodate 1,500 feet of coiled tubing – or even a straight loop – in the backyard. However, a large office building complex would likely present significant space and/or cost challenges, unless, like in Toronto, a district-wide approach is feasible.[10]

A ground source heat pump system is typically sized to meet expected cooling loads, although systems will often suffice for a great proportion (80 to 100 percent) of heating loads as well. A backup heating source is recommended for colder climates, such as New Jersey.

Costs, while variable, can be generalized to about $2,500/ton for residential applications, but drilling (for vertical systems) adds a significant additional cost. For a residential system, the final capital cost may be two to three times greater than a conventional system. On the operating side, various sources report energy savings of 25-50 percent, yielding paybacks of three to 10 years. The mechanical equipment is generally considered durable, with fewer moving parts than boilers and chillers, and the outdoor tubing carries warranties of up to 50 years.

**Matrix Review**

- **Site ( ):** Geothermal heat pumps require between 250 and 1,000 feet of tubing for each ton of heating and cooling. Accommodating a large horizontal installation on an urban or suburban site can be problematic. Vertically oriented systems require less space, but can involve expensive drilling. Geothermal applications can be applied in a hybrid system to supplement the heating and cooling load of a conventional system, but this application is much more applicable to new construction projects and not likely to fit NJDOT needs for existing facilities.

- **Energy ( ):** Below about 10 feet, ground temperatures remain relatively constant, and below approximately 20 feet they do not fluctuate measurably. Ground source heat pumps can yield substantial energy savings (25-50 percent).

[10] The 4,700 ton Louisville system utilizes the principles of ground source heat pumps, but is an exception in configuration and execution: the buildings sit directly over an aquifer. Three wells descend 130 feet, and draw up water to a 140,000 gallon tank, which in turn supplies three heat exchangers.

- **Cost (➲):** First costs are relatively high, and can increase significantly if drilling is involved. Operational costs are generally substantially lower than conventional systems.

- **Local (➲):** Contractors/installers are available in the region, but no state incentive programs exist that are specific to geothermal (although geothermal qualifies for many general renewable energy programs).

## ENERGY EFFICIENCY AND ENERGY CONSERVATION MEASURES

### Overview

| EFFICIENCY[11] | |
|---|---|
| Category | Rating |
| Site | ↑ |
| Energy | ➲↑ |
| Cost | ➲↑ |
| Local | ↑ |

Energy conservation measures (ECMs) and energy efficiency strategies, while not renewable energy per se, are nonetheless important to consider when developing alternative energy strategies – especially for older facilities. Although the blanket term "energy efficiency measures" will be used in this section, ECMs generally denote the reduction of energy usage (a motion sensor to control office lights, for instance) while energy efficiency involves the optimization of equipment (changing the office lights to compact florescent or LED bulbs, for example). These strategies can be used separately or in tandem, depending on project goals and anticipated economic payback.

Often, energy efficiency measures are simple to perform, have short payback periods, and reduce overall electrical or thermal loads significantly. With reduced loads comes the possibility of smaller, less expensive renewable energy installations with greater impact.

### Technology

A broad range of energy efficiency measures are available, depending on the project goals, circumstances, and desired payback period. Measures may be as simple as improving insulation, replacing inefficient fixtures and appliances, and upgrading windows or, at the opposite end of the spectrum, may involve the reconfiguration or replacement of major building systems. This review will not attempt an exhaustive treatment of such measures, but rather draw attention to a few prominent systems of energy-related diagnosis, evaluation, and guidance.

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[11] Depending on the technology or strategy used, energy efficiency measures are highly variable in terms of both energy savings and costs.

## Applications and Characteristics

### Energy Audit

An energy audit is usually performed by an energy engineer specializing in the performance of audits for a given building type. Various levels of audit exist, but generally, the auditor will focus on the building envelope (including fenestration), mechanical systems, and appliances and fixtures. The process may be as simple as a walk-through, involve the analysis of utility bills and/or metering data or, at the top end, include dynamic modeling of energy characteristics. Although more involved audits will cost more, a comprehensive audit will provide guidance for reducing energy consumption and also an estimate of the potential energy impact and cost of each strategy.

### Commissioning

Building commissioning entails the balancing, adjustment, and configuration of major building systems (such as HVAC, for example) in order to achieve optimal performance and efficiency. In many cases, a substantial proportion of commercial building energy usage is due to poorly functioning systems (Texas A&M researchers estimated up to 20 percent). Although the commissioning of new buildings has become a prominent aspect of green building practice recently, in part due to LEED,[12] continuous commissioning is critical to maintaining building performance on an ongoing basis. Continuous commissioning, as the name implies, involves making adjustments and repairs to currently operating systems that, over time, have suffered reductions in performance. Often, commissioning will also include additional training and education for physical plant personnel, who may not initially possess the skill sets necessary to maintain complex, modern systems equipment.

Retro commissioning is a similar concept to new building commissioning and continued commissioning, but involves existing buildings that were never originally commissioned. Retro commissioning also is similar to an energy audit, but generally involves a more thorough examination of building operations.

Although commissioning incurs additional expense, the payback is often quite rapid – Texas A&M's Energy Systems Lab reports simple paybacks averaging 2 years, with 1-year paybacks possible.

### Energy Star Buildings and LEED-EB: O&M

Both the Federal Government's Energy Star program and the United States Green Building Council's LEED for Existing Buildings: Operations and Maintenance (LEED-

[12] LEED stands for "Leadership in Energy and Environmental Design," and is a trademark of the United States Green Building Council. LEED has become the de facto standard for green building in the United States.

EB: O&M) programs provide essential guidance for attaining more energy-efficient physical plants. These systems can be used in tandem. Energy Star provides a useful tool, called Portfolio Manager, which allows physical plant managers to track energy and water consumption on-line across a portfolio of buildings. This allows for the identification of underperforming properties and the verification of efficiency improvements. LEED-EB provides a comprehensive checklist (extending well beyond energy efficiency) for improving the sustainability of existing buildings. In addition to providing useful performance benchmarks, the LEED-EB: O&M *Reference Guide* offers sample strategies (including commissioning and achieving Energy Star Building certification) for reducing electric and thermal loads. Although participation in the certification program (which provides verification and recognition of performance improvements) requires a fee, many building owners choose to follow LEED guidance without seeking formal certification.

**Matrix Review**

- **Site ( ):** Many energy efficiency strategies can be accomplished with only minor physical changes, and even major building system interventions rarely require significant additional space.

- **Energy ( ):** Variable: Energy efficiency measures worth implementing will offer significant energy savings in relation to cost or difficulty.

- **Cost ( ):** Variable: Many energy efficiency measures offer very rapid paybacks. The facility owner is at liberty to select interventions with acceptable payback periods.

- **Local ( ):** Energy auditors and commissioning engineers are widely available in the region, and many energy efficiency strategies can be implemented by non-specialist electrical or mechanical engineers, contractors, or facility personnel.

# APPENDIX C

# SOLAR PHOTOVOLTAICS FOCUSED REVIEW

## INTRODUCTION

This document builds on the general overview of solar photovoltaics (PV) outlined in the *Summary Scan of Renewable Energy Technologies*. The intention is to provide context for photovoltaic project development at NJDOT.

## OVERVIEW

Solar photovoltaic (PV) systems harvest energy directly from sunlight, in the form of direct current (DC) electricity. PV provides unique flexibility – from rigid, mounted panels to building-integrated thin film membranes – and is highly scalable. Applications range from handheld consumer electronics to residential, one-kilowatt systems to major, multi-megawatt commercial applications.

In just the last quarter century, solar PV has evolved from a relative novelty into a well-established technology; in the U.S., installed nameplate capacity has grown to over 1,106 MW in 2008, from only 85 MW in the year 2000.[13] However, even with capacity increases exceeding 25 percent each year since 2000, PV still comprises only 0.1 percent of all electricity produced nationwide – and no state generates more than 1 percent of its electricity using PV. The range of PV-generated power prices have dropped significantly during this period, to about 21 to 37 cents/kWh in 2008, but, without incentives, PV remains far costlier than conventional sources (9.28 cents average retail cost, nationwide, and 14.44 cents, average, in New Jersey for 2008).[14] Nonetheless, the cost gap continues to shrink and the technology continues to improve, reflecting increased R&D and manufacturer incentives.

New Jersey has been among the county's greatest proponents of PV and offers a wide range of incentives to help neutralize the cost disadvantage. New Jersey ranks second among all states – behind only California – in installed PV capacity, with over 100MW as of fall 2009, and has aggressive plans to continue expanding its leadership in solar PV.

### Technical Description

The building block of the technology is the photovoltaic cell, comprised of two layers (called "wafers") of semiconductor (most often silicon). Typically, one wafer is treated, or "doped," with phosphorous, which creates an excess of free electrons (this is called the "n-layer," with "n" standing for negative character). The corresponding wafer is doped with boron, which attracts electrons (this is called the "p-layer," with "p" standing for positive character).

The n-layer and p-layer are placed together, yielding an electron barrier at the point of contact called the "p-n junction." The n-layer section of the p-n junction takes on a

[13] U.S. DOE EERE databook, page 23.

[14] U.S. EIA, http://www.eia.doe.gov/cneaf/electricity/epm/table5_3.html, 12/09/09.

positive charge, and the p-layer takes on a negative charge. The photons in sunlight that strike the p-n junction energize the electrons, which are released. The free electrons are attracted to the n-layer (now positively charged, with "holes" for electrons), but, upon reaching the n-layer, repel one another because they are of like charge. A wire, connecting the layers as a circuit, provides an outlet for the electrons, which can be diverted to power an electrical load or charge a battery.

A typical cell produces less than 1 volt of electricity. In a PV system, cells are strung together in parallel (to amplify current) or series circuits (to increase voltage) to create solar modules, which can be further combined into panels, and finally, PV arrays. Electricity generated from PV is direct current (DC), whereas many electrical loads (and, for interconnected systems, the grid itself) require alternating current (AC). Therefore, an inverter is placed between the PV array and the distribution panel in order to condition the power to service AC loads. Often, a junction box (connected to the breaker panel) and a power disconnect are located on the DC side of the inverter, and an AC disconnect is included for utility use (to prevent power islanding) between the inverter and the fuse box.

**Applications**

Solar PV's prized characteristics include scalability and flexibility. In concept, a photovoltaic system can range from a few cells providing less than a watt of energy for a solar calculator, to a large, multi-megawatt array with hundreds of panels. Systems can feature panels which are mounted (fixed and one or two axis) or set flat on rooftops, on the ground, poles, canopies, or a multitude of other structures or surfaces. With the addition of thin film panels, PV can be integrated into roofing membranes, siding, windows, and a host of other applications. While, from the standpoints of cost, power production, and regulatory issues, it may not be desirable to place PV on every roof, every lawn, and over every window, the wide variety of available PV systems make it possible.

**Power Production and Impacts**

Like most renewables, the power production (kWh) of PV is dependent on a number of factors both internal and external to the system. Of internal factors, conversion efficiency is critical. Efficiency is measured by the percentage of available power in the sun's rays that is converted into electricity – of the photons that strike the PV cell, only a certain portion are absorbed and produce power. The first PV cells, developed in the 1950s, featured conversion efficiencies of only 4 percent. Currently, commercial PV conversion efficiency ranges from 7 to17 percent or more, although efficiencies of nearly 40 percent have been achieved with experimental materials and cell structures.

A key factor in determining efficiency is the semiconductor used, although other system factors (addressed subsequently) remain important when assessing actual power production. The original, and still most prevalent, PV systems were comprised of rigid

crystalline silicon panels. Currently, a variety of additional semiconductors are in use, including amorphous silicon, cadmium telluride, and copper indium diselenide.[15] These materials, while generally costlier and less efficient, allow for a wider variety of applications, most notably thin film PV, which can be integrated into roofing membranes, building siding, or even placed over windows.

Panels and thin film photovoltaics have substantially different typical efficiency ranges. Generally speaking, crystalline silicon panels are more efficient, with conversion ranging from 11 to17 percent. Thin film technologies offer typical efficiencies in the range of 7 to 10 percent.

The primary external power production factor is insolation (*in*cidence of *sol*ar radi*ation*), a measure of the solar radiation energy reaching a given space in a given time. For PV, insolation is commonly expressed in kilowatt hours per square meter per day ($kWh/M^2$/day). Areas with fewer average hours of sunlight (Direct Normal Irradiance or DNI) and cloudy, hazy, or polluted atmospheric conditions receive less insolation; New Jersey, with a modest DNI of 4.2 hours/day, has a lower insolation rate than many Southwestern states, for example. NASA data for Trenton show average insolation of 3.63 $kWh/M^2$/day (roughly comparable to Boston and Milwaukee), whereas Anchorage, AK comes in at a meager 2.09 $kWh/M^2$/day and Honolulu registers 5.96 $kWh/M^2$/day.

PV can generate significantly more energy during summer months than in winter – Trenton, for example, receives peak insolation of 5.39 $kWh/M^2$/day in June, as opposed to a winter low of 2.9 $kWh/M^2$/day. This characteristic is a key advantage of PV; electricity consumption is typically higher during hot summer days (due to air conditioning, primarily), and unit charges are often significantly more expensive during peak periods. A properly sized PV system allows a customer-generator to engage in "peak shaving" – essentially removing the peak of the utility-purchased power curve by substituting electricity generated on-site. This practice is generally favored by utilities because, if broadly practiced, it can obviate the need for additional, expensive, and rarely used peak load capacity.

A sketch calculation for determining potential PV production can be undertaken by multiplying the DNI by the panel DC nameplate, and then factoring for conversion losses. For a 1 kW array in Trenton:

1 kW x 4.2 (DNI) x 365 (days/year) = 1,533 kWh x.77 loss[16] factor = **1,180** kWh/year.

The NREL PVWatts calculator, which uses the insolation factor to calculate production, derives a consistent figure: **1,179** kWh/year. Actual power production is a complex function of multiple system characteristics and will be addressed in a subsequent memorandum – the above figures suffice only for general guidance.

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[15] DOE Solar Energy Technologies Program.

[16] The default for NREL's PV Watts calculator.

## Environmental Impacts

While, by most standards, photovoltaics are less environmentally burdensome than conventional power sources,[17] they present challenges to sustainability nonetheless. This is true particularly from a life-cycle/"cradle-to-grave" perspective; at the cradle, obtaining feedstock (raw materials for semiconductor production) and growing and processing PV crystals may release SO2, NO2, and other toxics. Further, while photovoltaic energy generation itself is relatively benign, battery-based energy storage systems can, depending on the technology, increase overall system impacts several fold (up to 435 percent, according to one study[18]). At the grave, few materials recovery programs exist (First Solar and German manufacturer Deutsche Solar AG are notable exceptions), and these processes themselves generate emissions through thermal decomposition. However, in 30 years – the estimated retirement date for panels installed today – recovery and recycling is likely to be more prevalent.[19]

## Project Implementation

## Siting

A few basic guidelines should be considered when siting a PV array:

- PV cells should be exposed to direct sunlight (DNI); a panel placed in a shaded area or covered by vegetation will not perform optimally.
- Proper panel ventilation is important; solar PV is powered by photons – not by heat, *per se* – and like most semiconductors, cell performance diminishes with excessive heat (called "heat fade").
- To ensure long-term performance, both panels and films should be placed in locations that are generally secure, inaccessible to the public, and free from obstructions and debris (such as excessive dust or smoke). Most commercial PV systems now carry 20- or 25-year warranties, with minimal reduction in output, and – under proper conditions – many can last 30 years or more.
- PV sited near the load it powers or meter into which it feeds will minimize the installation costs of new conduit and/or trenching.

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[17] PV creates approximately 111 grams/kWh of CO2 equivalent emissions over the system lifetime, as opposed to 677g/kWh for the U.S. average energy mix.

[18] Williams, Boyd, Buonassisi. "Technology Choices for the PV Industry: A Comparative Life-Cycle Environmental Impact Perspective." *Proc. 20th European Photovoltaic Solar Energy Conference and Exhibition*, Barcelona, Spain (2005).

[19] Renewable Energy World Magazine.

## Orientation

For the northern hemisphere, the best static orientation for PV is generally southern facing. The optimal tilt angle depends on the latitude of the installation. The following table gives the range of optimum solar angles for fixed panels.[20]

| Site Latitude | Tilt Angle |
|---|---|
| **0°-15°** | 15° |
| **15°-25°** | Same as latitude |
| **25°-30°** | Add 5°to local latitude |
| **30°-35°** | Add 10°to local latitude |
| **35°-40°** | Add 15°to local latitude |
| **40°+** | Add 20°to local latitude |

In practice, the optimum angle should be determined for each site individually. The optimum angle during winter is steeper than during summer, so for projects installing static mount PVs, the optimum angle may depend on when maximum generation is desired. Panels can be angled to maximize output in summer or winter (or a given midpoint), depending on load profiles and utility rate structures.

While a majority of systems are fixed mount, some advanced products are designed to track the sun, rotating the panel angle incrementally throughout the day to maximize daily efficiency and electric production. Although power production will be greater, variable tilt mounting adds cost and complexity to the system.

## Surface Area

As a general rule, modern crystalline silicon photovoltaic panels are rated for 8 to12 watts per square foot of area. For example, a 100-square-foot array can be expected to yield a nameplate capacity of approximately 800 W to 1.2 kW. Thin film is roughly half that, at 4 to 6 watts per square foot. This does not mean, however, that 100 square feet of surface area (such as roof space) will accommodate a 1 kW system; in addition to the area of the PV panels themselves, arrays may be angled to optimize light capture and panels must be spaced to allow for proper airflow and cooling – without shading adjacent cells.

New alternatives are available to increase the panel-to-surface area ratio. Cylindrical photovoltaics, under the brand name Solyndra, place cells in a 360 degree formation to maximize the sun angle without tilting (a white membrane roof reflects sunlight back to cells facing the roof surface). These systems also provide for air flow and wind relief. The capacity of Solyndra tubes is 7 to 9.5 watts per square foot.

[20] www.oksolar.com.

## Loads and Securement

The structural weight requirements of PV panels are generally between 3 to 5 pounds per square foot, not including the connection system, which is well within the typical structural limits of most roofs.[21]

PV systems must be designed to withstand local wind loads. Traditional PV panels are solid, exposed surfaces and therefore subject to wind loading. Thin film generally offers minimal wind resistance, and, as previously mentioned, Solyndra arrays are configured to avoid presenting significant surface area to wind loads. Maximum wind loads for New Jersey range between 90 mph and 120 mph, depending on location (generally stronger near the coast).[22]

For flat roofs, three primary securement options are available: rack-mounted, ballasted, or adhesive-mounted PV systems. With rack-mounted and ballasted options, tilted or flat arrays may be used. Tilted panels generally produce more output per module, but require more space to avoid shading one another. Since self shading is not a concern for flat-mounted panels, more solar collection per square foot of roof area may be achieved. Adhesive-mounted PV roofing systems consist of thin film photovoltaics adhered or laminated to the roofing membrane. Certain membrane roof manufacturers, such as Sarnafil, offer PV-integrated membranes.

Rack mountings allow for panel tilting on otherwise flat roofs, but require additional waterproofing of penetrations (specifications for waterproofing should be based on roofing manufacturers' recommendations). Ballasted systems keep modules in place on the roof deck by weight, rather than mechanical securement, aided by aerodynamic module design. However, some types of roofing may be incompatible with ballasted systems; a roofing contractor should be consulted before determining a securement system.

The main mounting options for ground systems are roof-ground racks and poles. Roof-ground racks, as the name implies, may be used for either roofs or ground systems. They allow for the arrangement of panels into large, same-tilted clusters. Pole mounts elevate a small aluminum or steel rack above ground level, and are typically used with smaller panels.

## Equipment and Infrastructure

Besides the panels themselves, photovoltaic systems require additional equipment and infrastructure. The most crucial is the inverter. PV generates Direct Current (DC) power, whereas building electrical systems and the electrical grid itself use Alternative Current (AC) power. Therefore, an inverter is required to convert DC electricity generated by the PV system into AC power. The inverter must be matched with the

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[21] California Energy Commission, *A Guide to Photovoltaic (PV) System Design and Installation* (2001).

[22] New Jersey Builders Association.

wattage output of the solar panels to which it is connected – larger systems may require more than one inverter.

Inverters come in three basic types:

1. *Grid tie inverter*: For solar energy systems that are integrated with the grid, the inverter applies solar generated electricity to the building's distribution panel. The power may then be used to supplement loads within the building (in tandem with the utility company), or it may be fed into the utility grid. Grid connected inverters facilitate net metering, which allows the customer-generator to effectively use the grid for energy storage and permits the sale of excess power.

2. *Multifunction inverters*: Also for grid connected systems, multifunction inverters can also be connected to a battery bank and/or a standby generator. When no solar energy is available, electricity is drawn from the batteries first, and then from the grid after the batteries have drained.

3. *Stand alone inverter*: For remote solar energy systems (non grid connected), the stand alone inverter converts DC electricity to power AC appliances and equipment.

For most NJDOT facilities, and certainly for the selected sites, the inverters will be of the grid tie inverter type. As discussed subsequently, New Jersey utilities are required to purchase class I renewable energy from qualifying customer-generators (see *Interconnection and Net Metering*). This allows NJDOT to use the grid for energy storage, avoiding the expense and complication of batteries.

If, in the future, NJDOT should explore solar energy for remote facilities and therefore require stand alone inverters, charge controllers and solar batteries would be required. Charge controllers, placed in between the solar module and the batteries, regulate the charge and protects against overcharging. Solar batteries are typically of the lead-acid deep-cycle type, which last longer but are costlier than conventional batteries. If batteries are properly maintained they often last 10 to15 years, meaning that a PV system may require two to three battery changes during the lifespan of most solar panels.

## Costs

Average PV module costs on a dollar-per-watt basis have trended downward in the last decade, with a March 2010 survey finding an average retail price of $4.24/watt compared to approximately $5.40/watt in late 2001.[23] The range of price points is broad, varying by type (thin film is generally less expensive per watt than panels), size, brand, certifications, country of manufacture, and module quality and efficiency. PV modules generally make up approximately 60 percent of overall system costs, with

[23] "Solar Module Retail Price Environment" (March 2010). www.solarbuzz.com.

mounting, connection, and power conditioning equipment (also called Balance of System or BOS) constituting the remainder.

With few moving parts (other than variable tilt mounts, if applicable), operations and maintenance (O&M) costs for PV are low relative to other renewable energy sources. Panels typically require only an occasional cleaning, while BOS equipment (such as inverters or batteries) may require replacement once or twice during a given project's lifecycle. NREL estimates O&M expenses of approximately $25/kW capacity/year for a mid-sized commercial system (200 kW).

### Zoning and Permitting

As property of a state agency, NJDOT facilities are exempted from municipal zoning and development review requirements. Plan and code review for NJDOT facilities is conducted by the New Jersey Department of Property Management and Construction, rather than local inspectors. All permitting – including building, electrical, fire, and plumbing – is conducted by the New Jersey Department of Community Affairs, whose state inspectors are responsible for issuing approvals.[24]

### New Jersey Municipal Land Use Law

Although NJDOT is categorically exempted from local land use laws, it is important to note that the installation of solar photovoltaics is accommodated by the State enabling legislation, the New Jersey Municipal Land Use Law (MLUL),[25] through the following provision:

- *A use or principal structure in a district restricted against such use or principal structure*. Where a principal use is restricted by local zoning code, the board may consider special situations where the "benefits of the deviation would substantially outweigh any detriment." Alternative energy facilities and equipment have traditionally been considered inherently beneficial and, as of 2009, the M.L.U.L. now specifically includes alternative energy facilities in this category (N.J.S.A. 44:50D-70).

Two bills that relate to alternative energy generation in New Jersey were recently voted into law by the Legislature. They create changes to the MLUL that expand the opportunities for landowners to develop renewable energy facilities, either as-of-right in the appropriate zone or through an expedited variance process.

- S1303/A3052 (N.J.S.A. 40:55D-70; Passed November 2009): Defines "inherently beneficial use" as specifically including facilities and structures that supply electrical energy produced from wind or photovoltaic technologies.

[24] E-mail from Dennis Meszaros, NJDOT, 2/17/2010.
[25] N.J.S.A. 40:55D-70.

- A2550 (N.J.S.A. 40:55D-66.11; Passed March 2009): A renewable energy facility on a parcel or parcels of land comprising 20 or more contiguous acres that are owned by the same person or entity shall be a permitted use within every industrial district of a municipality.

### Air Safety

Although local land use laws do not have jurisdiction over the study facilities, both the Ewing and Newark facilities are located in the vicinity of airports, and Federal Aviation Administration (FAA) codes would prevail if applicable. Based on previous conversations with a customer-generator based in Elizabeth, New Jersey near Newark Liberty International Airport, the consultant team felt it prudent to investigate whether panel photovoltaics are, due to glare issues, considered a hazard to air safety by the FAA. A thorough review of CFR Title 14, "Aeronautics and Space," with particular focus on Section 77, "Objects Affecting Navigable Airspace," found no such prohibition. Further, FAA Engineering Brief No. 76, *Using Solar Power for Airport Obstruction Lighting* (2008), encourages the use of photovoltaic panels at airports.

Finally, based on FAA standards and the New Jersey *Air Safety and Zoning Regulations*, neither facility is actually situated within an airport safety zone and PV systems would not exceed the heights of surrounding structures.

## State Policy and Planning

### New Jersey Energy Master Plan

New Jersey's Energy Master Plan, released in December 2008, emphasizes renewable energy sources and energy conservation in order to reduce statewide energy consumption 20 percent by 2020. Specifically, the Energy Master Plan calls for 30 percent of New Jersey's energy needs to be met by renewable energy resources by 2020, significantly exceeding today's 6.5 percent standard (and 2020s 20 percent requirement). The plan also seeks a reduction of peak demand, to 5,700 MW, which, in addition to demand response incentives, on-site renewables can help achieve. Together, these initiatives target a 23 percent reduction of $CO_2$ from 1990 levels by 2020, a goal complemented and reinforced by the New Jersey Global Warming Response Act Recommendations Report, released in December 2009.

### New Jersey Office of Clean Energy (OCE)

OCE is the State's primary public resource for renewable energy programs, information, and incentives, serving residents, businesses, and local governments. Since 2001, OCE has supported the installation of over 5,100 solar projects, comprising more than 133,000 kW of new capacity.

### New Jersey Office of Energy Savings

The Office of Energy Savings, created in 2006 by Executive Order and housed in the Treasury Department, is charged with maximizing energy savings from state buildings.

Its principal activities include the purchase of bulk power (as with the Pepco-supplied electricity accounts in Ewing), conducting energy audits, and promoting renewable energy within the State's large portfolio of buildings.

## Governor's Energy Plan

During the campaign of current Governor Chris Christie, he presented an Energy Plan for his office. In particular, the plan stressed the need to incentivize wind energy in New Jersey using tax credits and reduce regulatory barriers to their development. The plan also suggested creating a more encouraging land use environment for the development of new solar power facilities.

### Interconnection and Net Metering

Because renewable energy resources such as sunlight and wind are inherently variable, the power they generate is rarely sufficient to power building loads at all times. Rather, renewable energy usually serves to reduce loads and provide power supplementation, while base loads are handled by the electric utility. Photovoltaics, for example, will reduce the need for utility-supplied electricity during hot summer days (when energy is typically most expensive), but will not generate a single kilowatt at night. An energy storage system, such as a battery, is needed to balance out supply and demand in remote (non grid-connected) applications, which often adds considerable expense and, potentially, environmental impacts.

In many instances, grid interconnection provides a relatively inexpensive means to attain power reliability (often eliminating the need for on-site storage) without affecting the customer-generator's ability to benefit from on-site generation. Grid interconnection allows a facility to feed power back to the grid when energy production exceeds consumption, and draw power when consumption exceeds production. A meter, on the customer side of the point of common coupling, keeps track of net inflows and outflows. Net metering, a closely related concept, entitles the customer-generator to receive retail credit for kWh generated, allows for excess kWh to be carried over into subsequent months, and provides for an annual monetary reconciliation. New Jersey-specific interconnection and net metering requirements are detailed below.

## Interconnection

Interconnection to the distribution grid[26] in New Jersey is administered by the relevant utility, following rules promulgated by the Board of Public Utilities (BPU) in *N.J.A.C 14:8-4*. These rules apply to customers that "generate class 1 renewable energy on their own premises," which includes solar- and wind-generated energy. Three levels of interconnection exist: 1) for inverter-based facilities generating 10kW or less, 2) for

[26] The distribution grid is a lower voltage grid (56kv and lower) managed by the utility for the delivery of energy to its customers. The transmission grid, with much higher voltages (110kv and above), is managed by independent State or regional organization under the authority of the Federal government.

systems of 2MW[27] or less, using certified equipment, and 3) facilities of 2MW or less, which do not qualify under levels one or two (e.g., do not use "certified" equipment).[28]

All three of NJDOT's facilities are likely to fall under level 2 interconnection. The level 2 interconnection review procedure, to be conducted by the appropriate utility, is set out in *N.J.A.C. 14:8-4.6*. The prospective customer-generator must first submit an "Interconnection Agreement," available from the utility, along with a fee for engineering review (current level 2 review is $50 + $1/kWh installed capacity, or $1,050 for a 1 MW system). Interconnection approval is mandatory if the customer-generator meets 10 specific requirements (*14:8-4.6(c-l)*), many of which assess the ability of the utility's area network to handle interconnection. These requirements will require a feasibility review during project development. After the proposed equipment is verified, it may be installed by the customer, after which it must be inspected by a local electrical permitting official, or, in NJDOT's case, the New Jersey Department of Community Affairs (see *Permitting*). Upon approval, the utility must install two-way metering equipment within 10 days, after which the system may be powered on.

Although a recently passed law (the *Solar Energy Advancement and Fair Competition Act*) will remove the 2MW cap in the very near future (perhaps before the publication of this report), a customer-generator still may not feed back more power than was supplied by the utility over "an annualized period." In effect, if a customer-generator's peak energy consumption over a 12-month period was, for instance, 100 kW, then that customer may not return more than 100 kW to the grid at a given moment.[29] The limit ensures that interconnection can be accomplished without costly equipment and infrastructure upgrades; if energy delivery at a certain wattage is available, then it is probable that reverse power flow at the same wattage is achievable with existing equipment.

## PJM Interconnection

Regional Transmission Operators (RTOs) and Independent System Operators (ISOs) operate under Federal Energy Regulatory Commission (FERC) guidelines to manage the high-voltage electricity (transmission) grid and operate wholesale electricity markets. PJM Interconnection (PJM) is the RTO for Washington DC and 13 States, including New Jersey. Customer-generators in New Jersey which have greater capacity than consumption, wish to enter daily energy markets, require direct connection to the transmission grid, or otherwise do not qualify under BPU rules, may apply for interconnection through PJM. This is a process of significant complexity oriented

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[27] Measured as alternating current (AC), which will be smaller than DC output due to conversion losses.

[28] "Certified" equipment complies with standards set forth by IEEE Standard 1547 and UL 1741, both of which are incorporated into the Administrative Code.

[29] It is important to emphasize the difference between kW and kWh, for which there is no formal limit. kW expresses the intensity of power flow at a given point, whereas kWh expresses the amount of power flow over time.

primarily toward merchant power generators and very substantial power consumers (E.g., manufacturing plants), and is not likely to be necessary for NJDOT.

**Net Metering**

Once interconnection compatibility is established, all qualifying New Jersey customer-generators may participate in net metering on a first-come, first-served basis. True to its name, net metering will result in a net energy bill for customers, with outflows deducted from inflows on a monthly basis, as tracked by the customer's meter. For example, if a customer consumes 1,000 kWh (inflow) and generates 500 kWh (outflow), the customer will be billed for the net inflow, or 500 kWh. If, in a given month, outflows exceed inflows, then a credit will be applied to the subsequent month's bill at the retail rate. If excess outflows remain at the conclusion of a one-year period (which, significantly, the customer chooses), then the customer is compensated according to the "avoided cost," or wholesale rate. Depending on the customer's generation and consumption characteristics, net metering may play a major role in determining financial feasibility and will be included in the subsequent project development pro formas.

**Renewable Energy Incentives**

**New Jersey**

The State of New Jersey offers a panoply incentives for renewable energy, including tax credits, rebates, loans, and other financial instruments. Many of these incentives are financed through charges imposed by the Board of Public Utilities and are reflected in energy customers' monthly utility bills. Not every incentive will be available or even advantageous for all customers. For example, as a public entity, NJDOT cannot benefit directly from the property tax exemption or sales tax exemption. However, should NJDOT choose to contract with a private solar developer through a power purchase agreement (PPA), the sales tax reduction would likely be reflected in the agreed-upon energy rate.

Currently, available incentives include:

***New Jersey Board of Public Utilities – Solar Renewable Energy Certificate (SREC)***

Electricity suppliers or providers serving retail customers (collectively Load Serving Entities or LSEs) in New Jersey will have to obtain at least 20 percent of their energy from qualifying renewable sources by 2020 (the Renewable Portfolio Standard, or RPS). SRECs allow suppliers to purchase renewable energy credits from producers of renewable electricity in order to meet the RPS requirements. Currently, any utility-connected and metered customer-generator producing more than one MW of solar power may be authorized to sell SRECs for up to 15 years on a single system. A Solar Alternative Compliance Payment (SACP), currently $693/MW, is in place as a penalty should LSEs fail to achieve the mandated solar RPS. The SACP is necessary to ensure a robust market for SRECs, although it effectively caps their value. Given the currently tight supply of SRECs in relation to the solar RPS, the auction price of SRECs

has remained stable at around 95 percent of the SACP over the past year (March auction price was $665). Certificates are valid for two years from the date of issue.

### *Property Tax Exemption for Renewable Energy Systems*

Property owners with photovoltaic systems can claim an exemption from property taxes. Property owners must apply for a certificate from the local assessor in order to reduce the assessed value to what it would be without the renewable energy system. Exemptions take effect the year after certification. Rules relating to the technical qualifications are administered by the New Jersey Board of Public Utilities (BPU) and the Commissioner of Community Affairs.

### *Solar Energy Sales Tax Exemption*

New Jersey permits full exemption from the State sales tax for all solar energy equipment. All major types of photovoltaic equipment are considered eligible for the exemption.

### *Clean Energy Solutions Capital Investment Loan/Grant Program*

The New Jersey Clean Energy Solutions Capital Investment program provides grants and loans for a variety of energy producing and energy saving applications. The minimum capital equipment costs should be at least $1 million, should create or maintain jobs in New Jersey, and must meet regulatory requirements relating to project award (see N.J.A.C. 7:27D-2.2 for details). Projects that intend to utilize SRECs are only eligible to receive an interest-free loan. In addition, a minimum of 50 percent of project costs must be covered by the project sponsor – including Federal funding – and total state funding may not exceed 50 percent of the project cost.

Loans are available for up to five million dollars, a portion of which may be issued as a grant. Interest is set at 0 percent for up to 10 years and amortization may be up to 20 years based on the depreciable life of the equipment. Grants may be awarded for either 80 percent of the amount requested or $2.5 million, whichever is less.

### *New Jersey Customer-Sited Renewable Energy Rebates*

In 2001 the New Jersey BPU approved funding for renewable-energy programs, including a customer-sited renewables rebate program for homes, businesses, institutions and nonprofits. As of the beginning of 2010, the rebate was at $0.90 per watt (DC). The rebate is available for systems with no more than 50kW of capacity and should be sized to produce no more than the historical amount of electricity consumed at a system's site. All commercial and industrial customers must apply for a Tax Clearance Certificate from the New Jersey Division of Taxation to be eligible for financial assistance under this program. In addition, the system must meet detailed siting criteria specified in program guidelines.

### *Renewable Energy Manufacturing Incentives (REMI)*

In 2009 New Jersey opened the Renewable Energy Manufacturing Incentive program, which provides rebates for homeowners and businesses that install photovoltaic system components manufactured in New Jersey. There is no limitation on the size of eligible projects but incentives are limited to the first 500 kW for nonresidential systems. In order to receive incentives applicants must apply through the Solar Renewable Energy Certificate program. Equipment must be made by a program-certified manufacturer. Total incentives range from $0.08 to $0.14 per watt DC, depending on sector, system size, and the type of eligible equipment incorporated into a system.

### *PSE&G – Solar Loan Program*

PSE&G of New Jersey offers loans for "behind the meter" photovoltaic systems to all customer classes in its electric service territory. The program will provide loans covering 40 to 60 percent of the cost of PV systems. Loans are only available to systems generating 500 kilowatts DC or less that are eligible for net metering and generate Solar Renewable Energy Certificates. The loan term currently is 15 years at an interest rate of 11.3092 percent.

## Table 1 - New Jersey State renewable energy incentives

| Incentive | Offeror | Type | Terms | Eligible Users | Max kW |
|---|---|---|---|---|---|
| **Solar Renewable Energy Certificate (SREC) ☑** | NJBPU | Saleable Attribute | • Must be certified by BPU;<br>• Saleable within 3 years of generation. | All | n/a |
| **Property Tax Exemption for Renewable Energy Systems ☒** | NJBPU and Department of Community Affairs and NJ Treasury (?) | Tax exemption | • System must certified eligible by local assessor;<br>• One year after certification, PV is removed from property value for the purpose of tax assessment | All (except public) | n/a |
| **Solar Energy Sales Tax Exemption ☒** | NJPBU and NJ Treasury | Tax exemption | • Solar equipment exempt from NJ sales tax | All (except public) | n/a |
| **Clean Energy Solutions Capital Investment Loan/Grant Program ☑** | NJ Clean Energy Program/NJ BPU | Subsidized Loan/Grant | • Minimum capital cost of $1 million;<br>• Must create or maintain jobs in New Jersey;<br>• 50%+ of project costs must be covered by project sponsor.<br>• Loan max $5MM, grant max $2.5MM;<br>• Projects using SRECs only eligible for interest-free loan. | All | n/a |
| **Customer-Sited Renewable Energy Rebates ☑** | NJ Clean Energy Program/NJ BPU | Rebate | • Rebate of 90 cents/watt. | All (industrial and commercial must obtain Tax Clearance Certificate) | 50kW |
| **Renewable Energy Manufacturing Incentives (REMI) ☑** | NJ Clean Energy Program/NJ BPU | Rebate | • Must install NJ-manufactured solar equipment;<br>• Must apply through SREC program. | For residents and businesses; | Incentives capped at first 500 kW for nonresidential systems |
| **Solar Loan Program ☑** | PSE&G | Subsidized Loan/Grant | • Loans covering 40 to 60 percent of the cost of PV systems;<br>• Current rate 11.3% for 15 years;<br>• Project must be eligible for net metering and generate SRECs | All | 500kW |

**KEY:** ☑NJDOT eligible ☒ NJDOT not eligible

## Federal

Federal incentives are oriented toward two primary groups, private entities, especially businesses, and state governments for the creation of loan programs.

*Modified Accelerated Cost-Recovery System (MACRS)*

The Modified Accelerated Cost-Recovery System (MACRS) allows businesses the opportunity to recover investments in certain renewable energy property by deducting depreciation. The MACRS establishes timeframes over which various property may be depreciated, ranging from three to 50 years. A five-year schedule for most types of solar, geothermal, and wind property has been in place since 1986.

*Business Energy Investment Tax Credit (ITC)*

The business energy investment tax credit (see 26 USC § 48) is a Federal credit for up to 30 percent of total expenditures on developing renewable energy systems. There is no maximum limit on the tax credit amount. Eligible equipment includes property used to generate electricity, heating and cooling water, solar light and other applications. In general, credits are available for eligible systems placed in service on or before December 31, 2016. The credit was expanded significantly by the *Energy Improvement and Extension Act of 2008* (H.R. 1424), enacted in October 2008. This law extended the duration of the existing credits for solar energy, fuel cells and microturbines, among other changes. The credit was further expanded by *The American Recovery and Reinvestment Act of 2009*, enacted in February 2009. Businesses that receive other incentives are advised to consult with a tax professional regarding the calculation of this tax credit.

*U.S. Department of Treasury – Renewable Energy Grants (commercial, utility)*

The Renewable Energy Grant program was developed as part of the American Recovery and Reinvestment Act of 2009. The program is administered by the U.S. Department of Treasury (IRS). The program offers a cash grant in lieu of the Federal Business Energy Investment Tax Credit (ITC). Grants are available to eligible property (see 26 USC § 48) placed in service by January 1, 2014 if construction begins in 2009 or 2010. The guidelines set the beginning of construction at the point where the applicant has incurred or paid at least 5 percent of the total cost of the property, excluding land and certain preliminary planning activities. For solar projects the grant may be equal to 30 percent of the basis of the property for solar energy. Eligible solar-energy property includes equipment that uses solar energy to generate electricity, to heat or cool water (nonpassive), or to provide solar process heat. Hybrid solar-lighting systems using fiber-optic distributed sunlight are eligible. Only tax-paying entities are eligible for this grant. Partnerships or pass-through entities for nontax-paying organizations also not eligible to receive this grant except in cases where the ineligible party only owns an indirect interest in the applicant through a taxable C corporation. Grant applications must be submitted by October 1, 2011.

*Clean Renewable Energy Bonds (CREBs) (government, commercial, utility)*

Clean Renewable Energy Bonds (CREBs) may be used primarily by the public sector to finance renewable energy projects. The list of qualifying technologies is generally the same as that used for the Federal renewable energy production tax credit (PTC). CREBs may be issued by government, electric cooperatives, and some lenders. CREBs are issued with a 0 percent interest rate. Some issuers have included incentives with the bond in order to attract investment. The borrower pays back the principal of the bond while the bondholder receives Federal tax credits rather than interest on the bond. Participants should apply to the Internal Revenue Service (IRS) for a CREBs allocation and then issue the bonds within the number of years specified by program administrators.

*Qualified Energy Conservation Bonds (QECBs) (Government)*

The Qualified Energy Conservation Bonds (QECBs) were created as part of the *Energy Improvement and Extension Act of 2008.* Bonds may be used by state and local governments to finance some types of energy projects. QECBs are qualified tax credit bonds similar to new CREBs and terms are similar between the programs. However, QECBs are not subject to the IRS application and approval process. Bond volume is instead allocated to each state by formula and each state is responsible for allocating the funds. A portion of the allocation must be to "large local governments" within the state based on the local government's percentage of the state's population. IRS Notice 2009-29 contains a list of the QECB allocations for each state and U.S. territory.

*U.S. Department of Energy – Loan Guarantee Program (Commercial, Industry, and Government)*

The U.S. Department of Energy (DOE) issues loan guarantees for projects that "avoid, reduce or sequester air pollutants or anthropogenic emissions of greenhouse gases; and employ new or significantly improved technologies as compared to commercial technologies in service in the United States at the time the guarantee is issued." The DOE is authorized to offer more than $10 billion in loan guarantees for energy efficiency, renewable energy and advanced transmission and distribution projects. Investment is promoted in three categories: 1) manufacturing projects, 2) stand-alone projects, and 3) large-scale integration projects that may combine multiple eligible renewable energy, energy efficiency and transmission technologies. The loan guarantee program generally does not support research and development projects. *The American Recovery and Reinvestment Act of 2009* extended the authority of the DOE to issue loan guarantees and appropriated $6 billion for this program to enter into guarantees until September 30, 2011.

*Renewable Energy Production Incentive (REPI) (government)*

The Federal Renewable Energy Production Incentive (REPI) provides incentive payments to develop systems that generate electricity using renewable energy technology. Qualifying systems must generate electricity using solar, wind, geothermal,

biomass, landfill gas, livestock methane or ocean resources. The production payment applies only to the electricity sold to another entity. Eligible electric production facilities include state governments, not-for-profit electrical cooperatives, public utilities, and other government-related entities. Qualifying systems are eligible for annual incentive payments for the first 10-year period of their operation, subject to the availability of annual appropriations in each Federal fiscal year of operation. The maximum incentive varies and in March 2010 was 2.1 cents per kilowatt hour.

## Table 2 - New Jersey State renewable energy incentives

| Incentive | Offeror | Type | Terms | Eligible Users | Max kW |
|---|---|---|---|---|---|
| **MACRS** ☒ | IRS | Deductions | • 5-year depreciation window | Commercial, Industrial | None |
| **ITC** ☒ | IRS | Tax Credit | • 30% of expenditures<br>• Generate electricity, heat/cool, solar process heat, solar lighting, | Commercial, Industrial, Utility | None |
| **Renewable Energy Grants** ☒ | Dept of Treasury | Grant | • Up to 30% of property for renewable energy | Commercial, Industrial, Utility | None |
| **CREBs** ☑ | Dept of Treasury | Tax Credit Bond | • Apply through IRS<br>• 0% Interest rate (some incentives have been required of seller in order to sell bonds)<br>• Tax credits are taxable.<br>• Credit amt may not exceed Federal *Energy Policy Act of 2005.* | Commercial, Industrial, Government | None |
| **QECBs** ☑ | IRS | Tax Credit Bond | • 0% Interest rate (some incentives have been required of seller in order to sell bonds)<br>• Tax credits are taxable.<br>• Credit amt may not exceed Federal *Energy Policy Act of 2005.*<br>• Not subject to IRS application | Commercial, Industrial, Government | None |
| **Loan Guarantee Program** ☑ | DOE | Guarantee | • Full repay less than 30 years or 90% useful life of capital asset. | Commercial, Industrial, Government | None |
| **REPI** ☑ | DOE | Payment | • First 10-year period<br>• Subject to annual appropriations<br>• Must sell electricity to other entity | Government | None |

**KEY:** ☑NJDOT eligible ☒ NJDOT not eligible